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Studies on diurnal air temperature pattern from daily maximum and minimum by estimating the parameters of sinusoidal and exponential models on weekly basis under semi arid climate of Hyderabad

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ABSTRACT

The sinusoidal and exponential models for day time and night time temperature pattern have been fitted to weekly mean hourly air temperature data recorded at Hayathnagar Research Farm of CRIDA, Hyderabad during 1995-2007 using an automatic weather station. The lag coefficient 'a' of the sinusoidal model ranged between 1.150 – 4.372 and night time temperature coefficient 'b' of exponential model ranged between 2.175 – 4.334 during 1st - 52nd standard meteorological weeks. Coefficient of determination (R^2) values were between 0.892 – 0.995 for the sinusoidal and between 0.931 – 0.988 for the exponential model. Goodness of fit was tested by Student's 't' statistics as well by the graphical plots of observed vs. estimated mean weekly diurnal temperatures during 2008.

Key Words: Sinusoidal, exponential, model, air temperature

Wherever cutoff temperatures are different from the maximum and minimum values of air temperature, say for spores multiplication or pest build up, the diurnal pattern thereof can provide very useful input to forecasting models. For stochastic models, such data are often generated with markov chain models (Hansen and Driscoll, 1982 and Kline *et al*. 1982). But for models where it is desirable to use actual weather data, other methods need to be employed. Several research workers (Johnson and Fitzpatrick, 1977a & 1977b; Parton and Logan, 1981; Adalberto, 1991 & Sadler and Schroll, 1997) have attempted to model the diurnal pattern of temperature from mean hourly temperature at different time periods. Butler (1992) used sinusoidal and exponential models (Parton and Logan, 1981) to simulate daily pattern of air temperature at International Crops Research Institute for Semi-Arid Tropics, Patancheru, Hyderabad. Goodness of fit was very good on some days but not so good on few other days. One possible reason could be that he used the coefficients of sinusoidal and the exponential models developed elsewhere under different climatic conditions.

MATERIALS AND METHODS

The air temperatures recorded in automatic weather station (AWS) at Hayathnagar Research Farm, Hyderabad during 1995-2008 have been used in this study. The AWS data were compared with manual data recorded with standard thermometers put in Stevenson screen. Regression equation coefficients were worked out and incorporated in logger programme. Hourly data were averaged to get mean weekly hourly data for all the 52 weeks for each year. Subsequently data from 1995-2007 were pooled to work out the parameters of both the models i.e. sinusoidal for day time hourly temperature and exponential for night time hourly temperature simulation. The two equations given below describe the two models and are slightly different from those of Parton and Logan (1981). In these equations a new constant 'c' has been introduced which was worked out from mean weekly diurnal temperature data as the original equation was not fitting very well under climatic condition of Hyderabad.

$$T(t) = (Tn + c) + ((Tx - (Tn + c))\, Sin\left(\pi \frac{t - 6.5}{D + 2a} \right)$$

$$T(t) = (Tn + c) + ((Ts - (Tn + c))\, Exp(-\frac{bH}{N})$$

Where

- T(t) = Temperature (°C) at local standard time 't'
- Tx = Maximum temperature (°C)
- Tn = Minimum temperature (°C)
- c = A constant (°C) – temperature difference between weekly mean minimum and that at 06:30 A.M.
- t = Local standard time in hours since 06:30 A.M. till sunset
- D = Day length in hours
- a = Lag coefficient
- Ts = Temperature at sunset (°C)
- N = Night length in hours (24-D)
- b = Night time temperature coefficient
- H = Time in hours since sunset to 06:30 A.M.

Day length (D) for Hayathnagar Research Farm, Hyderabad was calculated using standard equations (Allen et al., 1998). Night length (N) was taken as the difference between twenty four hours and day length (D). Equation 1

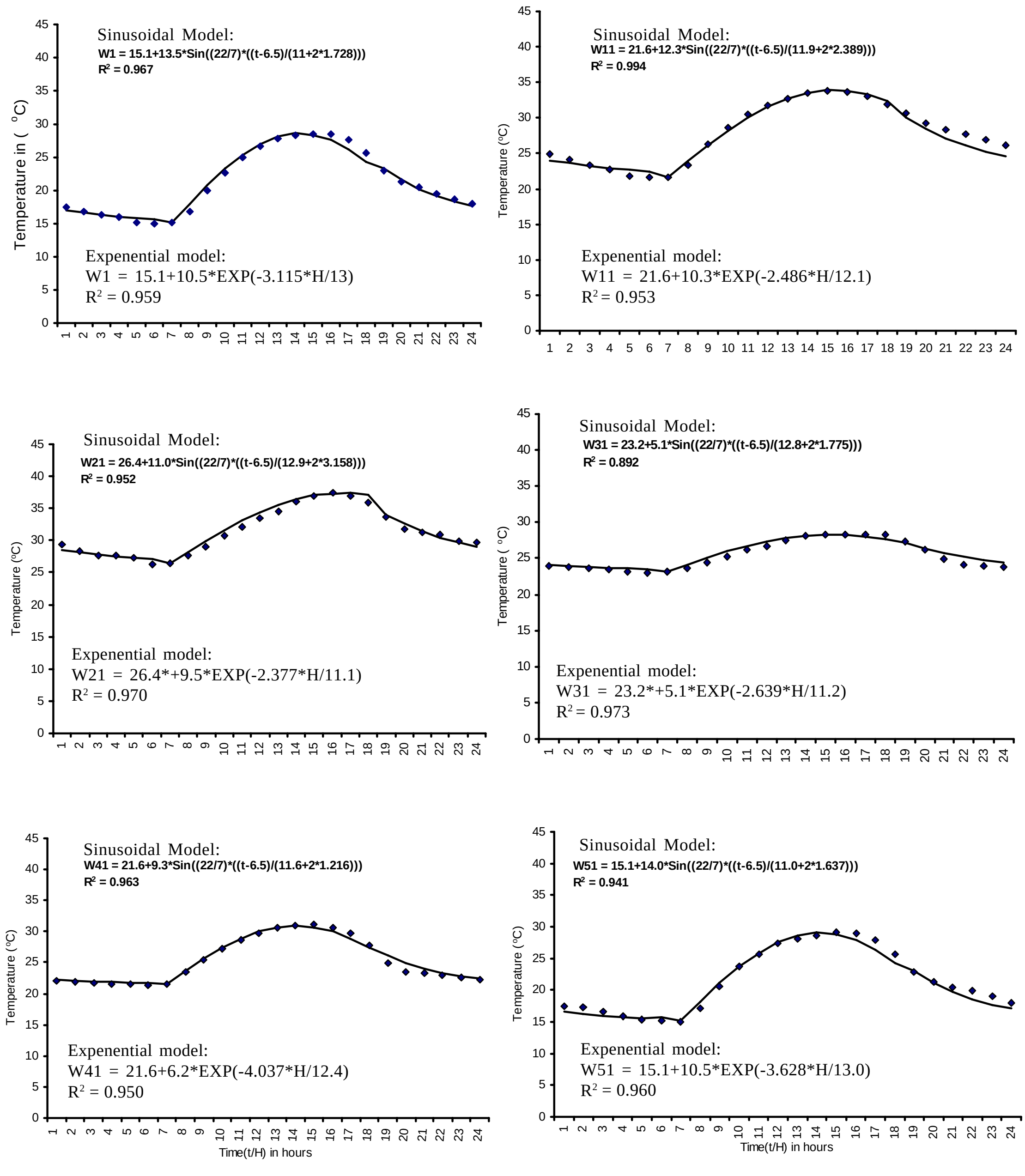

Fig. 1: Comparison of simulated (solid line) and observed (points) diurnal temperature in 1, 11, 21, 31, 41 and 51 week nos. at Hyderabad (2008)

was fitted to weekly mean hourly temperature between 06:30 A.M. and 05:30 P.M. during the period of 1995-2007. The lag coefficient 'a' was estimated by minimizing the least square difference between the observed and the estimated hourly temperature. Similarly Equation 2 was fitted to weekly mean hourly temperature between 05:30 P.M. to 06:30 A.M. during the same period of 1995-2007. Night time temperature coefficient 'b' was similarly estimated by minimizing the least square difference between the observed and the estimated temperature data during 05:30 P.M. to 06:30 A.M. Time of sunset was first worked out on daily basis by calculating hour angle (ù) using latitude and daily declination (ä). Subsequently corrections arising from equation of time as well as due to refraction of light were incorporated to get

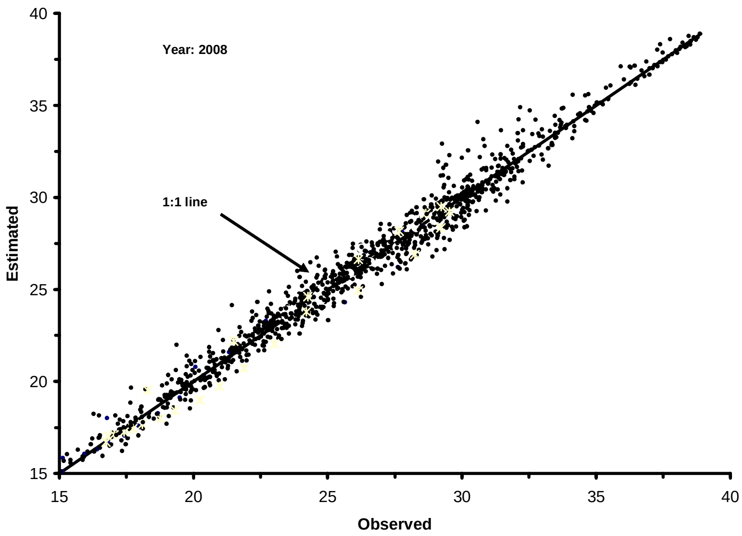

Fig. 2: Observed vs model (sinusoidal/exponential) diurnal temperature (°C) on weekly basis at, Hyderabad

apparent sun set hours for our location. Daily data was used to get the weekly values on time of sun set for this location. The constant 'c' was calculated from the weekly mean diurnal temperature as the difference between the minimum temperature and that at 06:30 A.M.

RESULTS AND DISCUSSION

Table 1 presents weekly mean maximum and minimum temperature along with constant (c), day length (D), lag coefficient (a) and coefficient of determination (R^2) in respect to sinusoidal model. Constant 'c' ranged between 0.3 and 2.1. The lowest values were during standard meteorological weeks 26 and 27. The highest value was during week no. 47. The constant 'c' gave the deviation between the mean temperature at 06:30 A.M. and the minimum during different weeks. The day length ranged between 11.1 and 13.2 hours. The lag coefficient 'a' was between 1.150 (week no. 40) and 4.372 (week no. 23). High values of coefficient of determination in the last column showed that the sinusoidal model represented well the temperature pattern within the boundaries defined.

Table 2 presents parameters and the coefficients etc. in respect to exponential model. Ts is the average temperature at sun set during different weeks. Time of sun set during different weeks varied between 17.66 (weeks 46 and 47) and 18.90hrs (weeks 27 and 28). Night time temperature coefficient was between 2.175 (week no. 23) and 4.334 (week no. 46). Coefficient of determination (R^2) was quite high showing that the exponential model too represented the temperature pattern from the time of sun set till 06:30 A.M. the next day.

Graphs were plotted for observed and estimated hourly air temperature during 2008 for all the 52 standard meteorological weeks. However, it was not feasible to present all the graphs here. Therefore, Fig. 1 shows the observed and the estimated temperature data for the weeks 1, 11, 21, 31, 41 and 51 representing all the major patterns at this location. The model values were reasonably well with the actual values.

Fig. 2 shows the scatter diagram on the hourly observed and the estimated temperature during all the weeks. A large number of data points lie around 1:1 line. This shows that both the models are performing satisfactorily. However, some data points are not so close to the line. This may be probably due to abnormal weather patterns arising from heat/cold conditions or occurrence of rainfall after extremes of temperature were recorded.

Table 3 presents observed and estimated mean daily temperatures along with 't' statistics for all the weeks. Estimated absolute 't' is quite low as compared to Table 't' of 2.013. This shows that the observed and the estimated mean daily temperatures do not differ significantly.

CONCLUSIONS

Coefficient of determination for both the models was more than 90 per cent. It was as high as 99 per cent for a week or two. Graphical plots and Student's 't' test showed

Table 1: Various parameters of the sinusoidal model for temperature pattern during day hours on weekly basis at Hyderabad (1995-2007)

Week No.	Max. Temp. Tx °C	Min. Temp. Tn °C	Constant ‘c’ °C	Day length D Hrs	Lag coefficient a
1	26.9	14.9	1.5	11.1	1.728
2	27.8	15.6	1.2	11.2	1.917
3	29.0	16.4	1.3	11.2	2.015
4	29.4	17.1	0.9	11.3	2.033
5	29.5	17.3	1.0	11.4	2.218
6	30.2	18.1	0.7	11.5	2.385
7	31.6	18.3	0.8	11.6	2.561
8	32.6	19.1	0.8	11.7	2.509
9	33.8	20.0	0.9	11.8	2.427
10	34.0	20.4	0.6	11.9	2.438
11	34.7	21.6	1.0	12.0	2.390
12	36.2	23.0	0.9	12.1	2.421
13	36.0	23.0	0.9	12.3	2.610
14	36.1	23.7	1.1	12.4	2.633
15	36.5	24.9	1.1	12.5	2.390
16	36.2	24.7	1.2	12.6	2.491
17	38.1	26.1	1.5	12.7	2.494
18	37.7	26.6	1.0	12.8	2.766
19	38.1	27.4	1.0	12.9	2.711
20	37.8	27.9	0.8	13.0	3.686
21	37.6	28.1	0.7	13.0	3.158
22	37.6	27.9	0.7	13.1	3.775
23	35.1	26.9	0.5	13.1	4.372
24	32.7	25.6	0.4	13.2	3.412
25	31.8	25.0	0.4	13.2	4.355
26	31.6	24.9	0.3	13.2	3.930
27	30.9	24.7	0.3	13.1	3.453
28	30.6	24.4	0.4	13.1	4.296
29	30.2	24.3	0.5	13.0	3.757
30	29.3	23.8	0.3	13.0	3.096
31	29.1	23.7	0.4	12.9	1.775
32	28.6	23.4	0.4	12.8	2.386
33	29.3	23.7	0.4	12.7	2.055
34	29.1	23.6	0.4	12.6	1.738
35	29.1	23.6	0.5	12.5	2.090
36	29.4	23.3	0.6	12.4	1.780

Table 2: Various parameters of the exponential model for temperature pattern during night hours on weekly basis at Hyderabad (1995-2007)

Week No.	Min. Temp. Tn °C	Temp. difference Ts-(Tn+c) °C	Time of Ts Hrs	Night length N Hrs	Night time temperature coefficient b	R^2
1	14.9	7.6	17.91	12.9	3.115	0.959
2	15.6	8.3	17.99	12.8	2.901	0.959
3	16.4	8.6	18.04	12.8	3.145	0.945
4	17.1	8.6	18.11	12.7	3.264	0.970
5	17.3	8.9	18.19	12.6	2.884	0.947
6	18.1	9.3	18.24	12.5	2.797	0.980
7	18.3	0.7	18.29	12.4	2.603	0.967
8	19.1	10.9	18.33	12.3	2.583	0.965
9	20.0	11.4	18.37	12.2	2.524	0.945
10	20.4	11.0	18.40	12.1	2.395	0.956
11	21.6	10.6	18.43	12.0	2.486	0.953
12	23.0	10.6	18.46	11.9	2.530	0.948
13	23.0	10.4	18.47	11.7	2.466	0.958
14	23.7	10.1	18.50	11.6	2.242	0.941
15	24.9	9.1	18.51	11.5	2.404	0.976
16	24.7	9.0	18.54	11.4	2.417	0.947
17	26.1	9.5	18.57	11.3	2.394	0.941
18	26.6	8.5	18.61	11.2	2.404	0.967
19	27.4	8.1	18.64	11.1	2.533	0.956
20	27.9	8.1	18.69	11.0	2.587	0.968
21	28.1	6.9	18.73	11.0	2.377	0.970
22	27.9	7.6	18.77	10.9	2.306	0.953
23	26.9	5.8	18.80	10.9	2.175	0.951
24	25.6	5.5	18.84	10.8	2.252	0.952
25	25.0	5.6	18.87	10.8	2.517	0.971
26	24.9	5.3	18.89	10.8	2.295	0.968
27	24.7	4.6	18.90	10.9	2.373	0.969
28	24.4	4.8	18.90	10.9	2.452	0.965
29	24.3	4.5	18.87	11.0	2.816	0.974
30	23.8	4.0	18.84	11.1	3.047	0.979
31	23.7	3.2	18.80	11.1	2.639	0.973
32	23.4	3.6	18.74	11.2	2.766	0.964
33	23.7	4.0	18.67	11.3	2.680	0.973
34	23.6	3.5	18.59	11.4	2.844	0.975
35	23.6	3.5	18.50	11.5	3.225	0.978
36	23.3	3.9	18.40	11.6	3.394	0.978
37	23.1	4.1	18.30	11.8	3.478	0.958
38	23.3	3.1	18.20	11.9	3.380	0.987
39	23.1	3.7	18.10	12.0	3.719	0.988
40	22.5	3.6	18.01	12.1	3.727	0.931
41	21.6	4.3	17.91	12.2	4.037	0.950
42	21.1	4.3	17.84	12.3	3.940	0.947
43	20.4	5.0	17.77	12.4	3.977	0.975
44	20.1	4.6	17.71	12.5	4.034	0.982
45	19.2	5.3	17.69	12.6	4.137	0.961
46	17.6	6.2	17.66	12.7	4.334	0.964
47	16.8	6.5	17.66	12.8	4.177	0.947
48	16.5	6.9	17.67	12.8	3.969	0.956
49	15.4	7.4	17.70	12.9	3.785	0.958
50	15.3	7.7	17.73	12.9	3.677	0.962
51	15.3	7.9	17.79	12.9	3.628	0.960
52	15.5	7.8	17.85	12.9	3.371	0.962

Table 3: Mean observed (2008) and estimated (sinusoidal/exponential model) daily temperature (°C) along with't' statistics at, Hyderabad Table't' at 46 d.f. = 2.013

Weeks	Mean daily temperature		't'	Weeks	Mean daily temperature		't'
	Observed	Estimated	Statistics		Observed	Estimated	Statistics
1	21.3	21.3	-0.010	27	28.9	28.8	0.246
2	22.3	22.3	0.024	28	29.4	28.9	0.702
3	22.5	22.4	0.099	29	28.3	28.6	-0.440
4	22.5	22.8	-0.267	30	25.0	24.9	0.099
5	22.7	23.0	-0.255	31	25.4	25.7	-0.610
6	23.3	23.7	-0.396	32	24.4	24.5	-0.339
7	23.9	24.2	-0.272	33	25.8	26.1	-0.490
8	25.3	25.4	-0.104	34	26.2	26.7	-0.766
9	25.7	25.3	0.293	35	27.1	27.1	-0.007
10	26.8	26.8	0.031	36	26.3	26.5	-0.266
11	27.9	27.7	0.164	37	25.0	24.9	0.355
12	25.2	25.1	0.182	38	25.7	25.8	-0.131
13	26.4	26.6	-0.203	39	25.6	25.7	-0.123
14	26.9	27.2	-0.308	40	26.1	26.0	0.163
15	28.8	28.9	-0.014	41	25.3	25.4	-0.191
16	30.8	31.5	-0.542	42	25.1	25.0	0.160
17	30.7	30.8	-0.065	43	23.9	23.8	0.090
18	32.4	33.2	-0.686	44	23.3	23.1	0.115
19	32.7	33.4	-0.726	45	22.7	22.3	0.219
20	33.2	33.7	-0.609	46	23.1	23.0	0.093
21	31.3	31.6	-0.264	47	23.4	23.4	0.028
22	32.3	32.6	-0.319	48	22.3	22.2	0.096
23	30.2	30.0	0.165	49	21.6	21.5	0.066
24	28.2	28.1	0.107	50	22.6	22.3	0.224
25	30.1	29.7	0.450	51	21.5	21.2	0.209
26	27.2	27.3	-0.190	52	21.2	21.0	0.215

that both the models are quite satisfactory for estimating diurnal air temperature pattern from daily maximum and minimum values. However, under abnormal weather events like heat/cold wave or heavy rainfall occurrence after recording of minimum or maximum temperature, one should either make some corrections or avoid use of these models.

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